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The Possibility of Extending Human Life

By

LOUIS I. DUBLIN, Ph.D., Statistician, Metropolitan Life Insurance Company, New York

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The subject which I am to consider has been a favorite one for speculation from the earliest antiquity up to our own time. The poets, prophets and philosophers have all been concerned with it. But, unfortunately, they have approached the subject with a bias. They have permitted their personal desire for extended life to determine their thought. In our own time, SHAW has given dramatic treatment to the subject, but he has approached it like the rest and has assumed that mere wishing can be converted into actual accomplishment. You and I will not approach the subject from that angle. We are concerned primarily with the facts. We are more fortunate than our predecessors. We have a body of knowledge which they lacked and, what is more important, a scientific method of analysis. We shall not say arbitrarily with the Psalmist, "The days of our years are three score and ten." We shall rather ask and attempt to answer a series of questions such as: "What are the conditions of health and mortality which determine the life span?" "What is the present duration of human life?" "How does that vary from place to place and from group to group?" "How much has it increased in various periods of time and what elements have led to the increase?" Finally, "How much more is there still ahead of us?" In such an approach, I hope there will be no room for dogmatism and no pretense to finality. We shall be humble seekers for the truth wherever that may lead us.

Obviously, the first step in our discussion is to discover a yardstick or measure of the human life span. No scientific discussion of the subject is possible without that. The first measure we have is one with which you are familiar, namely, the death rate. You know, for example, that the death rate of New York City last year was 11.17 per 1,000. This means that there occurred in that year approximately 11 deaths for each 1,000 of the population, or 112 deaths per 10,000 of the population, or, as we sometimes say, 1,117 deaths per 100,000 of the population. This figure is obviously a rough measure and tells us little or nothing with regard to the longevity of the people of the city.

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We immediately get into difficulties with this rate when we begin to compare the mortality of New York City with that, say, of Seattle, Washington, where the rate is lower. The fact is, that the populations of New York City and of Seattle are not constituted exactly alike as to the proportion of young and old people, and in other respects. If, for example, there are more babies and more old folks proportionately in New York City than there are in Seattle, that alone will materially increase the total death rate of New York City because it is among the babies and old people that mortality is heavy. This is universally recognized and, instead of the crude death rate for the whole population, we proceed to prepare death rates for specific age divisions of the population as well as for the whole. There is, for example, what we call the infant mortality rate. This means the death rate in the first year of life. We calculate, also, the death rates for the period of pre-school life, for other ages of childhood, for the broad span of early adult life, then of middle life and of old age. These values give us a measure of mortality for each age division of life and these may be compared for various places. The finer the subdivision of age, the more precise the comparison of mortality becomes.

Let me show you, for example, how a table of specific death rates looks for a large population, such as a group of states called the Registration States of the United States in the year 1920. When the series of rates is plotted on cross-section paper and a fairly smooth line is passed through the points, a characteristic hook-shaped curve is produced, such as is shown on the right side of the chart on the following page.

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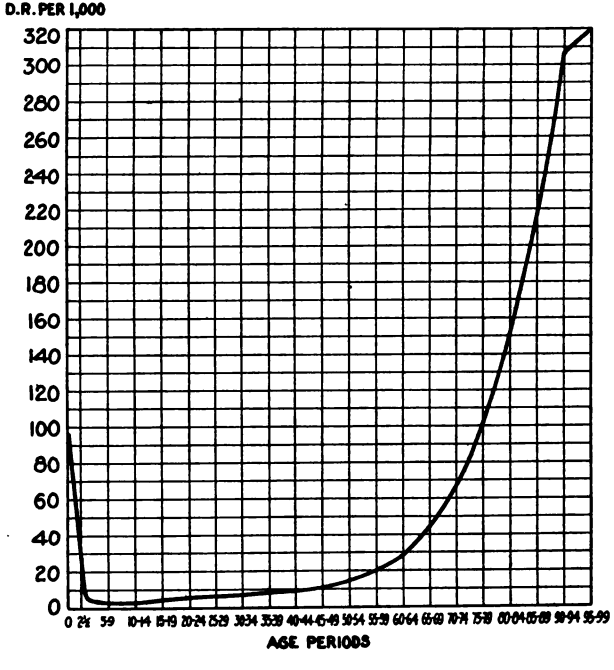
Chart I.

Deaths per 1,000 Population at Specified Age Periods United States Registration States, 1920

Population, Deaths and Deathrates per 1,000.
United States Registration States, 1920.

Age Period	Estimated mid-year Population	Deaths	Deathrates per 1,000
All Ages—Total	86,043,627	1,118,070	12.99
Under 1	1,772,022	170,911	96.45
1	1,835,551	36,106	19.67
2	1,852,486	16,503	8.91
3	1,879,711	11,184	5.95
4	1,832,228	8,306	4.53
5 to 9	8,966,917	26,535	2.96
10 to 14	8,355,822	19,046	2.28
15 to 19	7,416,925	30,276	4.08
20 to 24	7,442,685	42,386	5.70
25 to 29	7,462,571	48,224	6.46
30 to 34	6,727,817	48,600	7.22
35 to 39	6,479,122	50,436	7.78
40 to 44	5,335,665	46,225	8.66
45 to 49	4,846,495	50,438	10.41
50 to 54	4,028,420	56,587	14.05
55 to 59	3,051,838	60,537	19.84
60 to 64	2,544,264	71,462	28.09
65 to 69	1,756,534	75,344	42.89
70 to 74	1,191,366	78,507	65.90
75 to 79	739,270	73,120	98.91
80 to 84	347,470	52,959	152.41
85 to 89	134,657	29,131	216.33
90 to 94	33,531	10,281	306.61
95 to 99	7,589	2,427	319.81



This table gives a very good picture of mortality conditions prevailing in the Registration States at the time considered. But, there are many items to keep in mind, and they increase in number as our table becomes more precise for the age periods. It is difficult to compare the many items of one locality with those of another; some may be higher and others lower, producing a confused picture of the whole. A more important defect is that the death rates, as such, throw no direct light on the fact of longevity which is, after all, what the public wants to know about. The technical concept of the death rate needs to be converted into another measure which the average man can understand and use. This need has led to the production of another table which converts the multitude of specific death rates for a given area into the number of deaths in each age interval among a stationary population of 100,000 and then into the average length of after-lifetime at each age and in particular at birth. The "Life Table" does this.

Let me show you, for example, a life table of the population of a group of states reflecting the conditions of mortality which prevailed in the year 1910. (See Table 1 on pages 5 and 6.) Notice that we begin with 100,000 individuals from their moment of birth and that we trace their decline, in number, from year to year until all have disappeared by death. The table is, therefore, an epitome of the life cycle of this group of 100,000 individuals. The second column shows the number of survivors at the beginning of each year of age; the third column shows the number that died at each year of age; the fourth column gives the rate of mortality in each year of age. These are the death rates we considered previously; but they are now given for each year of age. They are the basic facts from which all the other figures follow.

TABLE 1.

Life Table, 1910

Entire Population of the Original U. S. Registration States

Age Interval (1)	Number Alive at Beginning of Age Interval (2)	Number Dying in Age Interval (3)	Mortality Rate per 1,000 (4)	Total Population Living in Current and Higher Age Interval (5)	Complete Expectation of Life (6)
0–1	100,000	11,462	114.62	5,148,536	51.49
1–2	88,538	2,446	27.62	5,056,683	57.11
2–3	86,092	1,062	12.34	4,969,588	57.72
3–4	85,030	666	7.83	4,884,059	57.44
4–5	84,364	477	5.65	4,799,376	56.89
5–6	83,887	390	4.66	4,715,260	56.21
6–7	83,497	327	3.91	4,631,568	55.47
7–8	83,170	274	3.30	4,548,235	54.69
8–9	82,896	234	2.82	4,465,202	53.87
9–10	82,662	204	2.47	4,382,423	53.02
10–11	82,458	187	2.27	4,299,863	52.15
11–12	82,271	180	2.19	4,217,498	51.26
12–13	82,091	182	2.22	4,135,317	50.37
13–14	81,909	193	2.36	4,053,317	49.49
14–15	81,716	210	2.57	3,971,505	48.60
15–16	81,506	232	2.84	3,889,894	47.73
16–17	81,274	256	3.16	3,808,504	46.86
17–18	81,018	285	3.52	3,727,358	46.01
18–19	80,733	315	3.89	3,646,483	45.17
19–20	80,418	344	4.28	3,565,907	44.34
20–21	80,074	375	4.68	3,485,661	43.53
21–22	79,699	398	5.00	3,405,774	42.73
22–23	79,301	412	5.19	3,326,274	41.94
23–24	78,889	418	5.29	3,247,179	41.16
24–25	78,471	425	5.42	3,168,499	40.38
25–26	78,046	432	5.54	3,090,240	39.60
26–27	77,614	440	5.67	3,012,410	38.81
27–28	77,174	451	5.85	2,935,016	38.03
28–29	76,723	465	6.06	2,858,067	37.25
29–30	76,258	479	6.28	2,781,576	36.48
30–31	75,779	493	6.51	2,705,557	35.70
31–32	75,286	511	6.78	2,630,025	34.93
32–33	74,775	530	7.09	2,554,995	34.17
33–34	74,245	550	7.40	2,480,485	33.41
34–35	73,695	568	7.72	2,406,515	32.66
35–36	73,127	588	8.04	2,333,104	31.90
36–37	72,539	605	8.33	2,260,271	31.16
37–38	71,934	617	8.59	2,188,034	30.42
38–39	71,317	631	8.84	2,116,408	29.68
39–40	70,686	644	9.11	2,045,407	28.94
40–41	70,042	658	9.39	1,975,043	28.20
41–42	69,384	674	9.72	1,905,330	27.46
42–43	68,710	693	10.09	1,836,283	26.73
43–44	68,017	716	10.52	1,767,919	25.99
44–45	67,301	740	10.99	1,700,260	25.26
45–46	66,561	766	11.52	1,633,329	24.54
46–47	65,795	795	12.08	1,567,151	23.82
47–48	65,000	821	12.63	1,501,754	23.10
48–49	64,179	846	13.18	1,437,165	22.39
49–50	63,333	873	13.77	1,373,409	21.69
50–51	62,460	897	14.37	1,310,512	20.98
51–52	61,563	929	15.08	1,248,500	20.28
52–53	60,634	970	16.01	1,187,402	19.58
53–54	59,664	1,025	17.17	1,127,253	19.89
54–55	58,639	1,084	18.49	1,068,102	18.21

TABLE 1.—*Continued*

Life Table, 1910

Entire Population of the Original U. S. Registration States

Age Interval (1)	Number Alive at Beginning of Age Interval (2)	Number Dying in Age Interval (3)	Mortality Rate per 1,000 (4)	Total Population Living in Current and Higher Age Interval (5)	Complete Expectation of Life (6)
55–56	57,555	1,153	20.03	1,010,005	17.55
56–57	56,402	1,225	21.72	953,027	16.90
57–58	55,177	1,289	23.37	897,237	16.26
58–59	53,888	1,346	24.97	842,705	15.64
59–60	52,542	1,404	26.73	789,490	15.03
60–61	51,138	1,462	28.58	737,650	14.42
61–62	49,676	1,521	30.62	687,243	13.83
62–63	48,155	1,587	32.96	638,328	13.26
63–64	46,568	1,656	35.55	590,967	12.69
64–65	44,912	1,718	38.25	545,227	12.14
65–66	43,194	1,773	41.06	501,174	11.60
66–67	41,421	1,826	44.08	458,866	11.08
67–68	39,595	1,877	47.41	418,358	10.57
68–69	37,718	1,928	51.12	379,701	10.07
69–70	35,790	1,974	55.14	342,947	9.58
70–71	33,816	2,013	59.52	308,144	9.11
71–72	31,803	2,044	64.29	275,334	8.66
72–73	29,759	2,065	69.38	244,553	8.22
73–74	27,694	2,072	74.82	215,827	7.79
74–75	25,622	2,070	80.78	189,169	7.38
75–76	23,552	2,057	87.37	164,582	6.99
76–77	21,495	2,028	94.35	142,059	6.61
77–78	19,467	1,981	101.74	121,578	6.25
78–79	17,486	1,920	109.78	103,102	5.90
79–80	15,566	1,854	119.10	86,576	5.56
80–81	13,712	1,786	130.28	71,937	5.25
81–82	11,926	1,696	142.17	59,118	4.96
82–83	10,230	1,565	153.06	48,040	4.70
83–84	8,665	1,409	162.58	38,592	4.45
84–85	7,256	1,255	172.97	30,632	4.22
85–86	6,001	1,103	183.80	24,004	4.00
86–87	4,898	954	194.85	18,555	3.79
87–88	3,944	816	206.84	14,134	3.58
88–89	3,128	689	220.13	10,598	3.39
89–90	2,439	571	234.31	7,814	3.20
90–91	1,868	466	249.62	5,660	3.03
91–92	1,402	371	264.66	4,025	2.87
92–93	1,031	289	279.90	2,809	2.73
93–94	742	219	295.12	1,923	2.59
94–95	523	162	310.17	1,290	2.47
95–96	361	117	325.02	848	2.35
96–97	244	83	339.74	546	2.24
97–98	161	57	354.55	344	2.14
98–99	104	39	369.73	212	2.04
99–100	65	25	385.46	127	1.95
100–101	40	16	401.91	74	1.85
101–102	24	10	419.14	42	1.76
102–103	14	6	437.37	23	1.67
103–104	8	4	456.77	12	1.59
104–105	4	2	477.48	6	1.50
105–106	2	1	500.22	3	1.41
106–107	1	1	524.82	1	1.33

In 1910, the infant mortality rate in this group of States was 114.6 per 1,000 births. If we apply this infant mortality rate to 100,000 births, there will be 11,462 deaths in the first year of life. There will, therefore, be 88,538 survivors at the beginning of the second year. The actual rate of mortality of the second year of life is applied to this number and a total of 2,446 decedents results. There are left, 86,092 survivors to begin the third year. In the same way, the application of the actual mortality rate to each succeeding number of survivors, at each age, gives the mortality history of the entire group until all have passed away. The important point to remember is that we begin with the mortality rate prevailing at the successive ages in any one year of time and apply it to our population of 100,000 at birth and to the survivors at each succeeding age until all are accounted for.

Let us now examine this table at the other end of life. Observe that there are 40 persons who celebrate their 100th birthday. Notice that these 40 people will altogether live a sum of 74 years before they all pass away. This figure is shown in the fifth column. This fifth column shows the number of years of life which the persons at any age will survive before all have passed out. So, by working the table backward, we find that, at the moment of birth, our group of 100,000 people have ahead of them a total of 5,148,536 years, which is, of course, an average of 51.49 years for each one of them. That is how the average length of life at birth, or what we usually call the Expectation of Life, is obtained. It is this figure which we use as the best index of the life span. Remember that this entire structure is based on Column 4, that is, the rate of mortality per 1,000 which prevails in the calendar year, for which the table is made. All of the other columns follow from Column 4. The life table is not as complex as it appears to be.

This method of measuring the life span is essentially accurate, is simple in construction, once the graduated rates of mortality are obtained, and produces figures for various places and various groups of people which are comparable. It is usually difficult to compare the health conditions of different countries or even of different cities in the same country by comparing their death rates, because of the varieties of age constitution of the people in the several places or because of so many other conditioning factors which affect the death rates. The life table irons out these differences. It applies the actual facts of mortality for the whole span of life and, later, gives the resulting values of expected longevity for the average individual of the group.

Longevity in the United States at the Present Time

With this as a background, let us become familiar with some of the very obvious facts of longevity at the present time. First, observe that the expectation of life at birth was nearly 51.5 years in 1910. The maximum expectation occurs in the third year when it is 57.72 years; that is because the child of three has already overcome the heavy initial mortality in the first two years of life. Even at age 10, the expectation is greater than at birth and for the same reason. But, from this age onward, the expectation declines regularly with every advancing year of life. At 25, the expectation in 1910 was 39.6 years; at 40, 28.2 years; at 50, nearly 21 years. That means that persons surviving to age 50 may, on the average, expect to survive to age 71. Some, of course, will die in their fiftieth year and some may be centenarians. That, I hope, is clear. But, the average individual at 50, if we may conjure up such an imaginary person, may, with reason, expect to live to age 71; or, as we put it, the average length of life remaining to each one of the survivors at age 50, is 21 more years. Even at 70, there are still more than nine years of expectation and so on in a diminishing degree to the end.

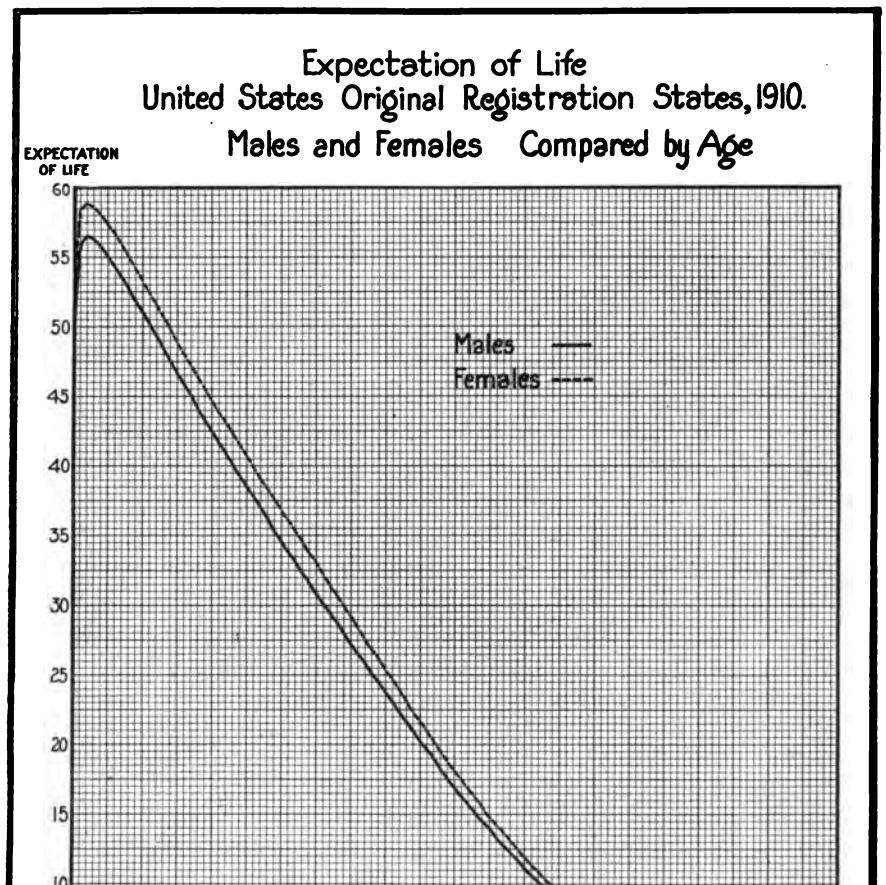
The table we have been considering is for a total population and has made no distinction of sex. Sex is, however, a very important element in mortality. You know that the mortality of women is less than that of men. Their expectation of life is, therefore, greater. The life table for the two sexes tells us how much greater. The following table, and Chart II on page 9, show the facts for the original Registration States in 1910, at selected ages, for males on the one hand, and for females on the other. The females have an expectation at birth three and one-third years greater than for males; at 30, it is more than two years greater; at 50, it is a year and one-third greater; and, at 70, about one-half year greater.

Table 2.

Complete Expectation of Life at Specified Ages—Males and Females in United States Original Registration States, 1910

Age	Males	Females	Age	Males	Females
0	49.86	53.24	30	34.70	36.79
1	55.94	58.37	40	27.32	29.15
2	56.59	58.94	50	20.32	21.67
3	56.33	58.63	60	13.95	14.90
4	55.79	58.08	70	8.83	9.38
5	55.11	57.39	80	5.10	5.37
10	51.07	53.31	90	3.01	3.05
20	42.48	44.66	100	1.81	1.91

Chart II.


Expectation of Life
United States Original Registration States, 1910.
Males and Females Compared by Age
EXPECTATION OF LIFE
60
55
50
45
40
35
30
25
20
15
10
5
0
Males
Females
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110
AGE

Longevity in Principal Countries of the World

The following table shows how the duration of life varies from place to place in the civilized world, reflecting the varieties of health standards and of well-being prevailing in the various countries.

Table 3.

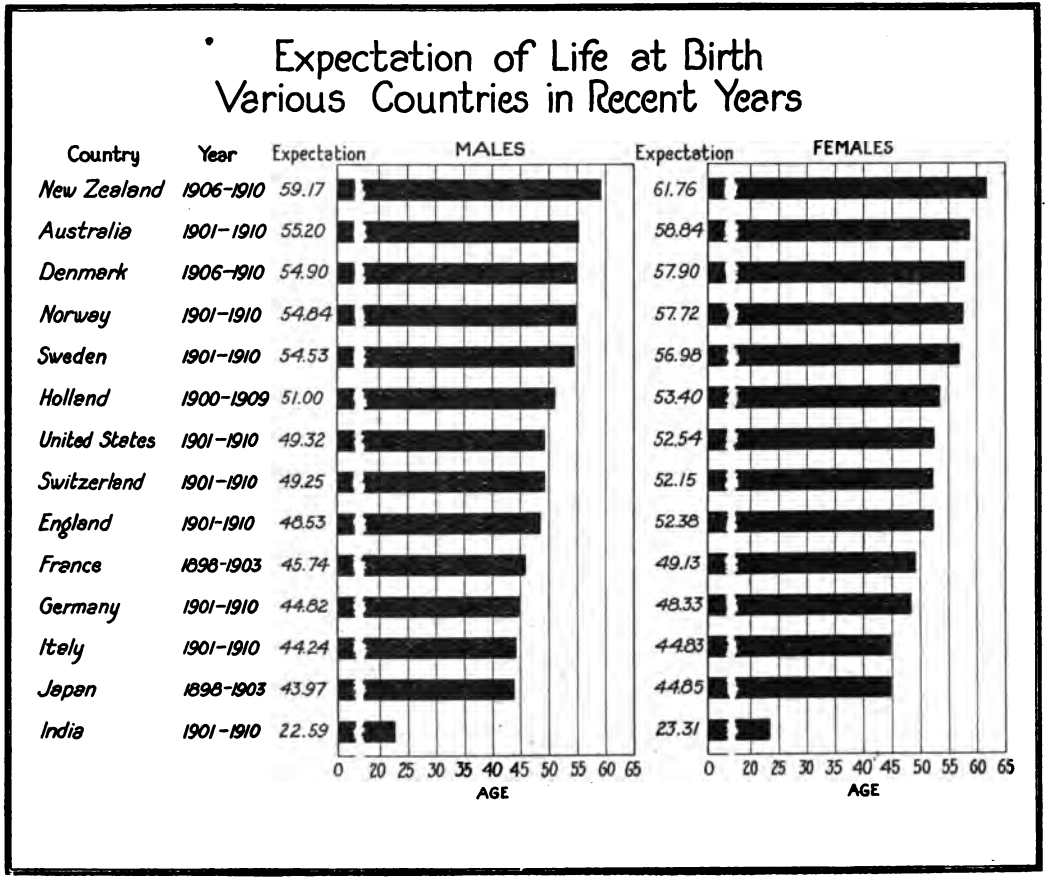
Complete Expectation of Life at Specified Ages—Various Countries in Recent Years

Country	Year	Males				Females			
		0	30	50	70	0	30	50	70
Australia	1901-1910	55.20	36.52	21.16	8.67	58.84	39.33	23.69	9.96
Denmark	1906-1910	54.90	38.00	22.10	9.30	57.90	40.10	24.10	10.00
England	1901-1910	48.53	34.76	19.76	8.39	52.38	37.36	21.81	9.25
France	1898-1903	45.74	34.35	20.26	8.42	49.13	36.93	22.14	9.21
Germany	1901-1910	44.82	34.55	19.43	7.99	48.33	36.94	21.35	8.45
Holland	1900-1909	51.00	37.80	21.80	8.90	53.40	38.80	22.90	9.40
India	1901-1910	22.59	22.44	13.97	6.17	23.31	22.99	14.28	6.22
Italy	1901-1910	44.24	35.94	20.73	8.02	44.83	36.58	21.47	8.02
Japan	1898-1903	43.97	33.44	18.97	7.89	44.85	34.84	21.11	8.77
New Zealand	1906-1910	59.17	38.78	22.67	9.38	61.76	40.48	24.30	10.31
Norway	1901-1910	54.84	38.86	23.96	10.57	57.72	40.24	25.31	11.23
Sweden	1901-1910	54.53	38.57	23.17	9.85	56.98	40.20	24.74	10.53
Switzerland	1901-1910	49.25	33.80	18.90	7.78	52.15	36.10	20.71	8.15
United States	1901-1910	49.32	34.80	20.59	8.96	52.54	36.75	21.86	9.52

Note.—See also Chart III on following page.

New Zealand shows the greatest expectation of any of the countries listed in the above table. For males, the complete expectation was 59.2 years at birth, as compared with 49.3 in the United States. The Australian figures follow next in order of excellence. The Scandinavian countries, Denmark, Norway and Sweden, are very close to Australia in the length of the life span. The conditions of England and Wales approximate those in the United States. France, Germany, Italy and Japan are a few years below the United States in the average duration of life. In India the life span is only about one-half of what it is in European countries. The important point to remember is the great diversity in the span of life in the various countries, ranging from 61.8 years for females in New Zealand to 22.6 years for males in India. You will realize why these differences occur in the light of the sanitary, social and economic conditions that prevail in the various parts of the world. You will understand also why the people of some countries enjoy great prosperity and a larger measure of well-being while those in others are always near or under the line of distress and general misery.

Chart III.


Expectation of Life at Birth
Various Countries in Recent Years
Country
Year
Expectation
MALES
Expectation
FEMALES
New Zealand 1906-1910 59.17 61.76
Australia 1901-1910 55.20 58.84
Denmark 1906-1910 54.90 57.90
Norway 1901-1910 54.84 57.72
Sweden 1901-1910 54.53 56.98
Holland 1900-1909 51.00 53.40
United States 1901-1910 49.32 52.54
Switzerland 1901-1910 49.25 52.15
England 1901-1910 48.53 52.38
France 1898-1903 45.74 49.13
Germany 1901-1910 44.82 48.33
Italy 1901-1910 44.24 44.83
Japan 1898-1903 43.97 44.85
India 1901-1910 22.59 23.31
0 20 25 30 35 40 45 50 55 60 65
AGE
0 20 25 30 35 40 45 50 55 60 65
AGE

Increase in Life Expection in the Last Century

A substantial increase in the life expectation has occurred in the last century. (See table on next page.) This fact is the best indication we have of the greatly improved material progress of the great mass of people in the civilized countries of the world. The figures for England and Wales are the most instructive for our purposes. The first life table for the population of that country described the period between 1838 and 1854. The average length of life was then nearly 41 years. A series of life tables follows the first and shows a successive gain from decade to decade. The seventh table, that for 1910 to 1912, gives an average expectation of nearly fifty-three and one-half years. There has, therefore, been a gain in the interval of seven decades of twelve and a half years. On the Continent, the best historical data are for Sweden. A table for the years 1816 to 1840, shows expectations of forty-one and one-half years. The last table (1901 to 1910), gives fifty-five and three-quarter years. These are gains of fourteen and a quarter years in the interval of eight decades. In our own country, the first table of any value is for Massachusetts (1855). The values agreed essentially with those for England and Wales for the corresponding period, the life expectation in both Massachusetts and in England and Wales being about forty years. In 1910, the Massachusetts figure had increased to fifty-one years, showing a gain of eleven years in the half century. In 1920, the figure was over fifty-five years or a gain of more than fifteen years in 65 calendar years. In the Registration States of the United States, we find an increase of six years between 1901 and 1920.

TABLE 4.

Expectation of Life at Birth

PRINCIPAL COUNTRIES OR STATES AT VARIOUS TIMES

Country—Year	Expectation at Birth	Country—Year	Expectation at Birth
ENGLAND AND WALES		HOLLAND	
1838-1854	40.88	1850-1859	37.32
1871-1880	42.98	1870-1879	39.55
1876-1880	43.56	1880-1889	43.75
1881-1890	45.42	1890-1899	47.60
1891-1900	45.95	1900-1909	52.20
1901-1910	50.45	NORWAY	
1910-1912	53.42	1856-1865	48.67
SCOTLAND		1871-1880	49.81
1861-1870	42.09	1881-1890	49.97
1871-1880	42.37	1891-1900	52.27
1881-1890	45.12	1901-1910	56.26
1891-1900	46.06	DENMARK	
1911	51.64	1835-1844	43.65
FRANCE		1860-1869	44.55
1817-1831	39.55	1880-1889	47.85
1840-1859	40.15	1885-1894	48.05
1861-1865	39.82	1895-1900	51.70
1877-1881	42.12	1906-1910	56.40
1898-1903	47.43	FINLAND	
ITALY		1881-1890	42.80
1876-1887	35.25	1891-1900	44.25
1899-1902	43.04	1901-1910	46.30
1901-1910	44.53	GERMANY	
1910-1912	47.38	1871-1880	37.01
BELGIUM		1881-1890	38.71
1881-1890	45.11	1891-1900	42.26
1891-1900	47.10	1901-1910	46.57
SWITZERLAND		1910-1911	49.04
1876-1881	41.90	PRUSSIA	
1881-1888	44.49	1867-1877	36.68
1889-1900	47.10	1890-1891	40.60
1901-1910	50.70	1891-1900	42.83
SWEDEN		1900-1901	43.95
1816-1840	41.53	1906-1910	48.22
1841-1845	44.27	BAVARIA	
1846-1850	43.48	1891-1900	39.48
1851-1855	42.57	1901-1910	43.78
1856-1860	42.31	SAXONY	
1861-1870	44.60	1891-1900	39.80
1871-1880	46.95	1900-1911	44.77
1881-1890	50.01	INDIA	
1891-1900	52.28	1881-1891	25.07
1901-1910	55.75	1891-1901	23.80
		1901-1911	22.95
UNITED STATES (Reg. States) 1901	49.24	MASSACHUSETTS	
1910	51.49	1855	39.77
1920 (Orig.Reg.States)	55.16	1890	43.48
1920 (Total Reg.States)	56.32	1895	45.35
		1901	47.75
		1910	51.19
		1920	55.25

There is another and perhaps better way to see how great has been the improvement in the life span in the last century or so. That is, to observe the age at which the original number of our life table population, 100,000, is reduced by one-quarter, one-half and three-quarters. The following table, and Chart IV on the next page, show the facts for England at the time of the first and last tables and for New Zealand at the time of its last table.

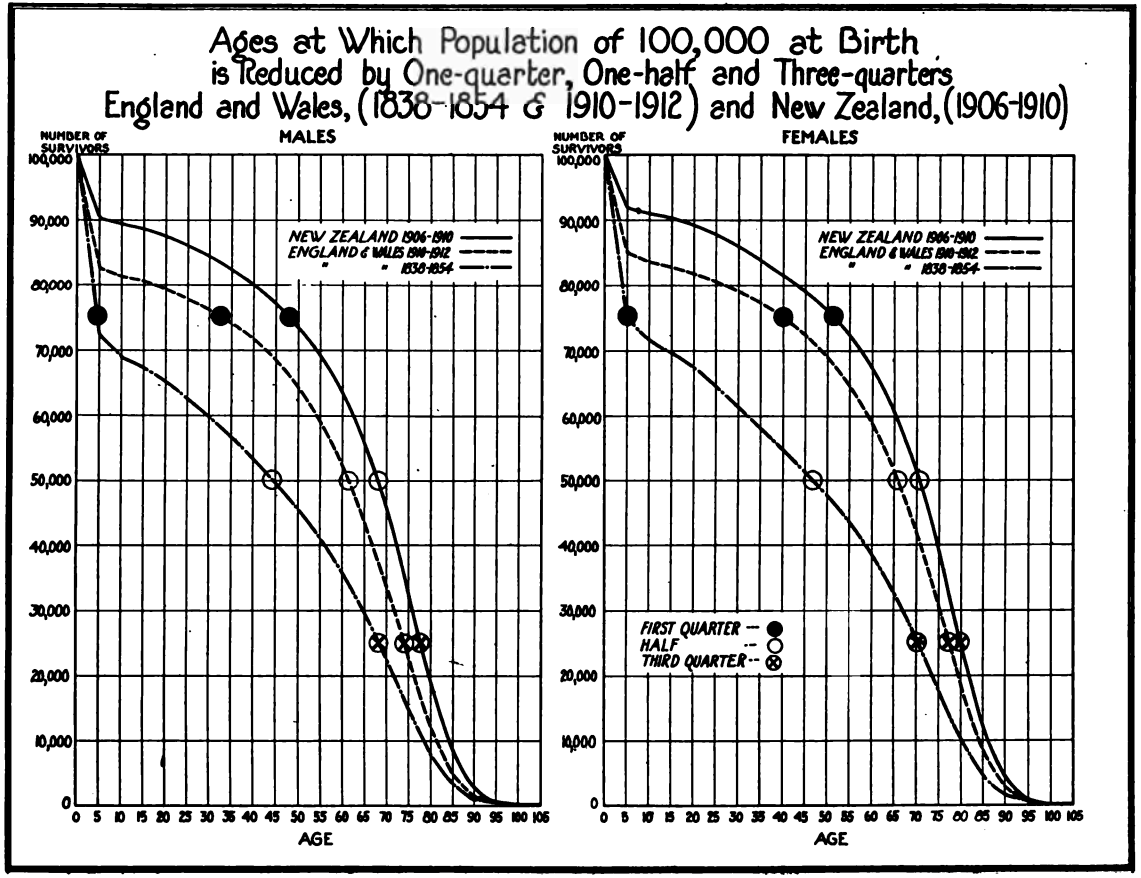
TABLE 5.

COUNTRY	Date of Life Table	AGE IN WHICH THE ORIGINAL NUMBER OF A GENERATION IS REDUCED BY—					
		ONE-FOURTH		ONE-HALF		THREE-FOURTHS	
		Males	Females	Males	Females	Males	Females
England.....	1838-1854	3.25	5.00	44.33	46.33	68.17	70.08
	1910-1912	33.25	40.00	61.33	65.67	73.83	77.08
New Zealand...	1906-1910	48.33	51.50	68.00	70.50	77.83	79.83

The same life tables also lend themselves to another interpretation. In England, at the time of the first table, only 29.5 per cent. of the male and 32.4 per cent. of the female population attained age 65, whereas at the time of the last table 43.5 per cent. of the males and 51.2 per cent. of the females attained that age. In New Zealand, where the best longevity conditions prevail, 55.9 per cent. of males and 60.5 per cent. of females reached the age of 65 in the period 1906 to 1910. As this is the age which closes the active working period of life, it must be obvious that that nation is the most productive, and its people enjoy the largest measures of longevity, and shall I add prosperity, which can bring the largest proportion of its people up to the threshold of old age.

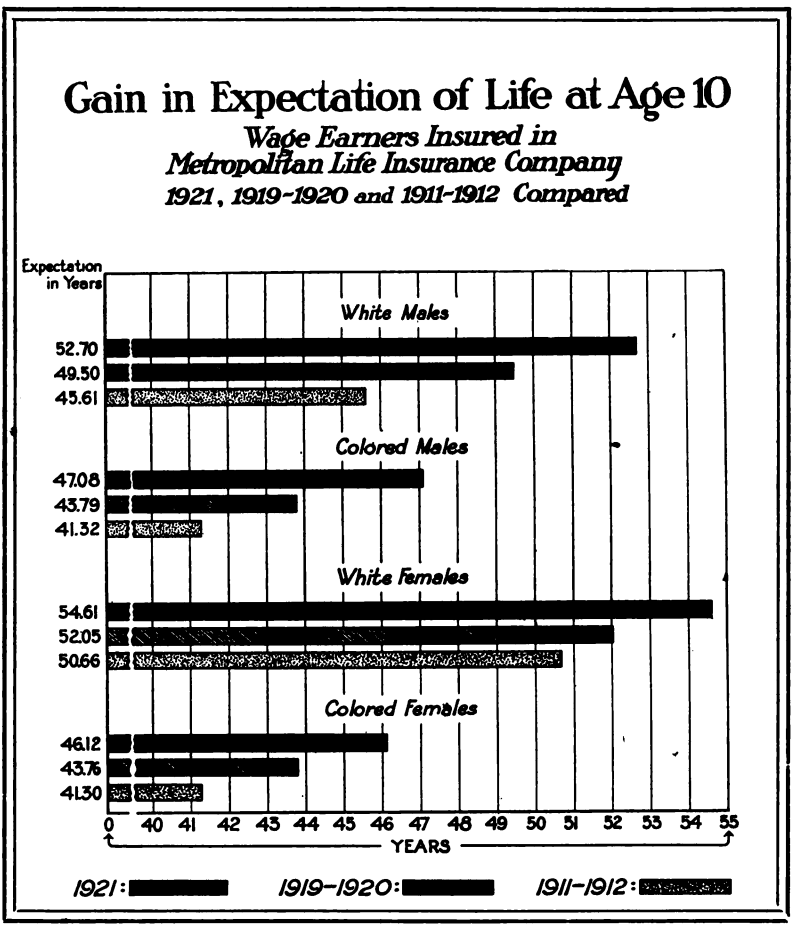
Possibly, the most encouraging results have been obtained among insured lives, where a definite effort has been made to extend the life span. In 1909, the Metropolitan Life Insurance Company began an active campaign of health education among its millions of Industrial policyholders. This was supplemented with the development of nursing care for those who were acutely ill. The death rate during this period showed continuous improvement, dropping about one-third in the decade. Accompanying this drop in the death rate, there was an increase of eight and one-half years in the expectation at birth for these insured lives representing the working population of America.

Chart IV.


Ages at Which Population of 100,000 at Birth is Reduced by One-quarter, One-half and Three-quarters
England and Wales, (1838-1854 & 1910-1912) and New Zealand, (1906-1910)
MALES
FEMALES
NUMBER OF SURVIVORS
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
NEW ZEALAND 1906-1910
ENGLAND & WALES 1910-1912
" " 1838-1854
FIRST QUARTER
HALF
THIRD QUARTER
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105
AGE

The following chart shows the gains in expectation of life at age 10 among the four classes of insured persons (white males, white females, colored males and colored females).

Chart V.



The significant thing about this insurance experience is the light that it throws on the possibilities of further life extension. The mortality rate and the corresponding average after-lifetime respond very quickly and favorably to intelligent effort. The same thing has happened in the general population of the United States and in the European countries whose figures we have quoted, but the response has been less pronounced, probably because conservation work was applied less exactly and less intensively. The lesson is forcibly

brought home that we are still far from having attained the maximum possibilities in the extension of human life under present conditions in any group among whom the experiment has as yet been tried.

The Possibilities of the Future

What, then, are the possibilities for extending human life? This question can have meaning only as it has reference to the present state of our knowledge of preventive medicine and applied sanitary science and to the present levels of human well-being. It would be futile for us to prognosticate on the basis of any substantial future advances in medical, surgical or sanitary knowledge, certain as we may well be that important advances will be made and within a reasonably short time. We are, therefore, virtually compelled, in seeking an answer to our question, to piece together a picture of an attainable mortality experience out of the best experience that now exists. There can be no complaint of undue optimism when we rest our case upon actual achievements or what is on the threshold of achievement. This, then, is our assumption. Let us see what that leads to in the actual working out of our case.

The most important single item of mortality is the record for the first year of life. Fifteen per cent. of all the deaths that occur each year are of children within the first year of age. Infant mortality cuts very heavily into the life expectation because a death in that year erases the entire expectation for that life, whereas a death at a later age, say forty or sixty, removes only relatively few years of life, and, as a result, the effect on the average is slight. Fortunately, there is compensation for high infant mortality, namely, its relative ease of prevention and control. In the Birth Registration Area of the United States, the infant mortality rate dropped in 1921 to 76 per 1,000 births. In New Zealand, in 1920, it was below 50 per 1,000 births for the entire country, and there are a large number of cities in the United States, some of good size, where the infant mortality at the present time is below 40 per 1,000 births. We have accordingly started our hypothetical life table with the basic assumption that an infant mortality rate of 38.2 expresses an entirely realizable figure under present conditions, although it is only a third as great as that in the 1910 Life Tables, which we have just examined. Do not be unduly disturbed by what looks like a very radical assumption of a too low infant mortality rate. It really is not at all extreme. If anything, it leans over to the side of conservatism, because the assumed value has not only been attained in any number of places, but there is every indication that it is attainable by the whole country

within a relatively short period of years. We can, in fact, surpass it by paying attention to one particular, namely, the suppression of the infant mortality of the first month in which hardly anything has as yet been achieved on a countrywide scale. In another place,* I have recently outlined a procedure which, I am confident, will do for early infant mortality what the general baby welfare movement of the last twenty years has accomplished for children above the first month. The detection and handling of syphilis in the mother, the control of the toxemias of pregnancy, and the provision of good obstetrics for the great body of parturient women, coupled with the type of nursing care now largely available in the cities of the United States, will give us what we hope for. This favorable level of the infant mortality rate has been amply demonstrated as attainable. Infant mortality rates of 20 per 1,000 births and even below that are on the horizon. We have assumed a higher rate of 38.

In like manner, we have proceeded on the general assumption that the mortality in the succeeding four years of childhood is materially reducible. Our assumed figures for the second, third, fourth and fifth years vary between 34 and 40 per cent. of the actual mortality rates for the respective ages in 1910. Each one of the values was determined with the greatest care, having in mind the rates prevailing in the most favored countries, and what we know can be done to prevent mortality from the diseases and conditions of the preschool years. Thus, we have assumed a mortality rate of 4.2 per 1,000 for the third year of life. In New Zealand, nearly fifteen years ago, the rate was 5.3. Our figure is only 20 per cent. below the relatively remote New Zealand figure. In the third year of life virtually two-thirds of the entire mortality is due to such infections as typhoid fever, diarrhea and enteritis, the four communicable diseases of childhood—measles, scarlet fever, whooping cough and diphtheria—tuberculosis and the respiratory diseases. Who will deny that these conditions are now within control, provided we mean to control them? How great is the promise for the eradication of diphtheria through the general application of methods now employed in this very city, *viz.*, that of wholesale inoculation of children with toxin-anti-toxin? Yet, diphtheria looms large in the mortality not only in the third year of life, but in all of the years of childhood after the first.

Between the ages of ten and sixty, in that broad fifty-year span of life, we have made one basic assumption throughout, namely, that mortality can be reduced to one-half of the figure which prevailed in 1910. This is an important point in the procedure of building up our hypothetical life table. Between ages five and ten, the values were

*"The Mortality of Early Infancy." Read before the Thirteenth Annual Meeting of the American Child Hygiene Association, October 13, 1922, Washington, D. C.

interpolated so as to give a smooth juncture between ages 3, 4 and 5 and the ages after ten. It meant graduating the values from 40 per cent. of the 1910 mortality at age five to 50 per cent. of the 1910 figure at age ten. At age ten, we used a death rate of 1.1 per 1,000; the New Zealand value was 1.4. The vital item in our procedure was, however, the assumption that in the age range covering virtually the entire active period of life from ten to sixty, the mortality is capable of a 50 per cent. reduction from the 1910 figure. Again, our values are, for the most part, only 20 per cent. below those for New Zealand in recent years. But, in that country, as in our own, there is still much preventable mortality from tuberculosis in the working period of life. There is also the serious mortality from occupational and other accidents. In the latter part of this broad age period, there is already a heavy death rate from the diseases of the heart, kidney and blood vessels, much of which is preventable and has actually been prevented or postponed in limited groups of the population.

Our assumed rates between ten and sixty are, moreover, very close to those attained by the best life insurance companies in their current Ordinary experience. At some of the ages, the actual insurance experience is even lower than the values we have assumed. We in the life insurance business are more and more impressed with the splendid possibilities before us for the further curtailment of mortality among insured persons. Through such procedures as the annual physical examination and the hygienic follow-up to encourage the insured to bring their impairments under medical supervision, we hope to attain large results. An investigation into the mortality of a group of Ordinary policyholders of the Metropolitan who had availed themselves of the privilege of the Life Extension Institute examinations over five years ago showed at the end of the period a mortality 28 per cent. lower than that of the best control group we could muster, having in mind all the logical requirements of the comparison.

We are especially optimistic as to the future because of the amazing reduction in the death rate from tuberculosis which is occurring throughout the world. Since 1911, the disease has declined 50 per cent. among those insured in the Metropolitan and almost as much in the general population of a number of progressive cities. The disease is not only declining rapidly in actual mortality, but the peak or maximum rate by age is constantly being pushed forward into the later years of life. This has the effect of extending the expectation. On the other hand, we are not doing so well with reference to the diseases and conditions which reflect personal hygiene and the general care and use of the human body. The death rates from the so-called degenerative diseases, like heart disease, Bright's disease, cerebral

hemorrhage and the other diseases affecting middle life and the older ages are not declining. We are making little headway in spite of increasing public and medical interest in them. These deaths represent heavy losses to the community because they involve in many instances people still in their prime and at the height of their usefulness. The development of a well-conceived campaign against these losses, organized along lines which have proved successful against tuberculosis, will, according to the best medical opinion, produce excellent results. Together, the three diseases—heart disease, Bright's disease and cerebral hemorrhage—curtail the expectation by about four years. A further reduction in the incidence of the acute infectious diseases, such as typhoid fever, diphtheria and acute rheumatism, which are so fruitful in producing damage to the heart, kidneys and vascular systems of young people, will bring important results, as will also the extension of health education and the inculcation of better health practices among adults. It is reasonable to expect that an appreciable part of the 50 per cent. mortality reduction postulated by our hypothetical life table will be accomplished through these means.

The further extension and the more intensive application of the life-saving campaign to industry likewise holds out much promise. The prevention of occupational mortality has scarcely been begun as a nation-wide effort. There can be no question that certain industrial processes widely developed throughout the country seriously shorten the life span. The effects of excessive heat, of poisonous fumes, of deleterious dusts and actual contact with poisonous substances, unduly long hours of labor, all result in raising the mortality rate of industrial workers far above those for the general population. The excellent physical endowment of industrial workers assures a greater life expectation under conditions of improved industrial hygiene than is actually attained at the present time. Occupational accidents alone are still responsible in the United States each year for as much as fifteen thousand deaths, for the most part of men in their prime. Employers of labor can give material aid in the campaign to reduce adult mortality in America one-half. The ever-growing interest of employers in safety measures and in shop sanitation gives much encouragement for the future.

Please notice that we have limited ourselves to those possibilities of life saving which are reasonably likely to occur on the basis of past experience. We have made no allowance for any possible saving from cancer, for example, because it would evidently involve more knowledge than we now have of the causative factors of this disease. In like manner, we have made no assumption of life saving in old age, that is from, say, age 70 onward, because during the last half century

there has been practically no improvement in the mortality among aged persons. The only liberty we have taken in the preparation of our hypothetical life table is to graduate the mortality values from 50 per cent. of the actual in 1910 at age 60 to 100 per cent. mortality at age 70. This provides a smooth and reasonable transition from a period where life extension is still somewhat possible to one where no substantial gains are at present in sight.

We are now ready to show you this hypothetical life table which expresses the best mortality we may hope for with our present knowledge and in the light of our actual achievements. (See table below.) The total expectation of life at birth is 64.75 years; or, for the purposes of easy reference, let us say, 65 years. This means an addition of ten years to the life span now prevailing in the United States which, as we have seen, is only 55 years. Notice that there is no sharp rise in the table after the first year of life, as there was

TABLE 6.

Hypothetical Life Table

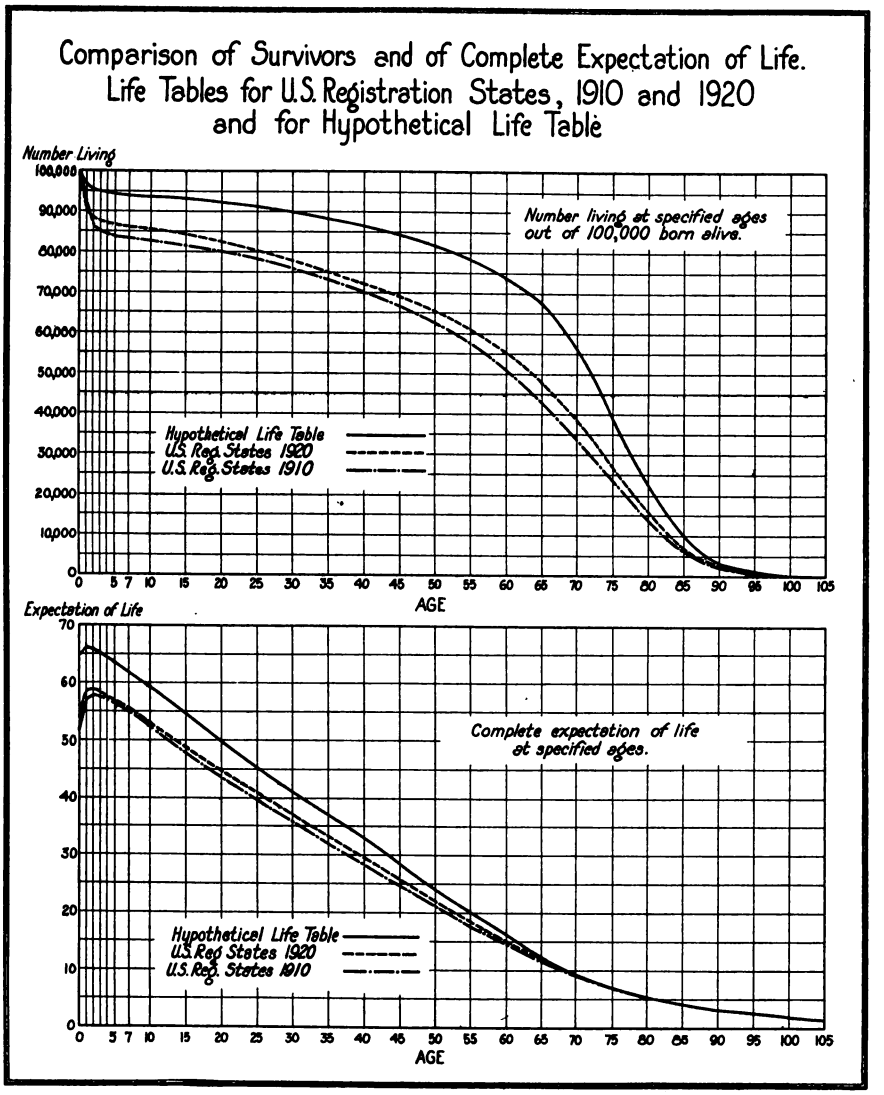
Age	Number Living in Specified Age Interval	Mortality Rate per 1,000	Expectation of Life
0	100,000	38.21	64.75
1	96,179	10.00	66.30
2	95,218	4.20	65.97
3	94,818	2.80	65.24
4	94,552	2.25	64.42
5	94,339	1.85	63.57
10	93,648	1.14	59.02
20	92,269	2.34	49.82
30	89,772	3.26	41.06
40	86,318	4.70	32.49
50	81,542	7.19	24.08
60	73,882	14.29	16.01
70	56,213	56.45	9.17
80	22,818	130.28	5.29
90	3,110	249.62	3.03
100	67	401.91	1.85

NOTE.—Constructed from Life Table for United States Registration States, 1910, on following assumptions as to mortality rates:

Age	Assumed Reduction from 1910 Rates
0 to 5	Approximately two-thirds
5 to 10	Two-thirds to one-half
10 to 60	One-half
60 to 70	One-half to no reduction
70 and over	No reduction

in the earlier life tables. That is because we have reduced the infant and child mortality to a third of the previous figures. According to our new table, a person of 20, that is, one who is about to enter active adult life, would have an average expectation of 50 years of after-lifetime. That means that those crossing the threshold of manhood and womanhood may expect, on the average, to attain age 70. What a curious confirmation our figures give to the biblical allotment of three score and ten!

Chart VI.



A comparison of our hypothetical life table with the expectation prevailing in the Registration States in 1920 indicates a possible gain of ten years at birth; of fully five and one-half years at age 20; of three and a quarter years at age 40; of two and one-half years at age 50; and of one and one-third years at 60; at 70 and thereafter there is no gain to be expected, because no improvement in the mortality rates was assumed in the construction of the table. The greater part of the gain is obviously limited to early life, where there is still the greatest opportunity for preventing mortality. But the possible gains in middle life are sufficiently large to justify every effort in their attainment.

How great these gains would actually be is shown by comparing the number of deaths now occurring in the United States each year with those which would occur under the death rates called for by our Hypothetical Life Table. The total death rate would be reduced from 13.0 to 8.6 per 1,000, assuming no change whatever in the age constitution of the present population. In other words, an extension of the expectation by ten years in accordance with the suppositions of our Life Table would be accomplished by a coincident reduction in the death rate of 33.8 per cent. On the new Life Table basis, there would be a total of close to 916,000 deaths in the United States as against a total of approximately 1,379,000 which occurred in 1920, or equivalent to a saving of 463,000 lives a year. The greatest saving would be accomplished in the first year of life. A reduction of the infant mortality to a third as assumed by us means a saving of 126,000 infants a year. In fact, the saving would be 171,000 children in the first five years of life. The saving, on our assumption of one-half mortality between the ages 10 to 60, is equivalent to a reduction of 250,000 in the number of deaths in that age period. These large figures show very strikingly how great are the stakes involved in the programme of life saving implied by the Hypothetical Life Table we have constructed. It is very encouraging in this discussion to remember that these savings are just as reasonable as are the assumptions of reduced mortality whose plausibility we have defended in our previous sections.

Possibly, in my assumption of virtually no improvement after the close of active life, I have opened myself to serious criticism. There are those who on plausible grounds see much improvement in mortality at the older ages as a possibility for the future. They are much impressed with the large results being obtained in small groups through emphasizing more intensive personal hygiene. They are not over-impressed with the fact that the last half century has shown no response at the older ages to the improved conditions of life. They

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profess to see that much of the mortality from the so-called degenerative diseases that prevails at the older ages can be curtailed by preventing the infectious diseases of early life, and by more reasonable and intelligent conduct of our personal lives. All of this seems very reasonable and I should regret very much if it were assumed from what I have presented that the span of human life is practically fixed and that no material extension of it can be expected beyond the average of sixty-five indicated by my life table. The figure that we have presented is simply a summary of what we believe to be the most probable figure, having in mind the present state of our knowledge. It is entirely conceivable that a medical discovery of the first order which would do for, let us say, chronic nephritis, what the newer therapy has accomplished for syphilis, or what promises to be accomplished for diabetes, would add somewhat to our maximum figure. The additional gain would not be very much because the saving would be at the advanced ages when the expectation is low by comparison. All of this, however, is for the future and it would be idle for us to dwell at this time on such possibilities.

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